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GUTs WITH EXCLUSIVELY $\Delta B = 1$, $\Delta L = 0$ R-PARITY VIOLATION

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Abstract

We study R-parity violation in the framework of GUTs, focusing on the case that R-parity is broken exclusively through $\Delta B = 1$, $\Delta L = 0$ effective interactions. We construct two such models, an $SU(5)$ and an $SU(5) \times U(1)_X$ model, in which R-parity breaking is induced through interactions with extra supermassive fields. The presence of only the Baryon Number violating operators $d^c d^c u^c$ requires an asymmetry between quarks and leptons, which is achieved either by virtue of the Higgs representations used or by modifications in the matter multiplets. The latter possibility is realized in the second of the above models, where the left-handed leptons have been removed from the representation in which they normaly cohabit with the right-handed up quarks and enter as a combination of the isodoublets in $(\overline{\mathbf{5}}, -\mathbf{3})$ and $(\mathbf{5}, -\mathbf{2})$ representations. In both models the particle content below the GUT scale is unaffected by the introduced R-parity breaking sector.

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1. Introduction. In contrast to the Standard Electroweak Model where B- and L-number conservation is automatic for the minimal field content, in the Supersymmetric Standard Model[1] renormalizable interactions among the standard chiral matter superfields can be present[2] which violate both B and L. These interactions are

$$\lambda_{ijk}l_il_je_k^c + \lambda'_{ijk}d_i^cl_jq_k + \lambda''_{ijk}d_i^cd_j^cu_k^c + \epsilon_il_iH\,. \tag{1}$$

The indices are generation indices. These terms can be avoided by imposing a discrete symmetry called R-parity and defined as $R=(-1)^{3B+L+2S}$, S being the spin. If R-parity is not an exact symmetry and the above interactions are present[3], the combination of the second and the third term in (1) results in proton decay through squark exchange at an unacceptable rate, unless the product of these couplings is extraordinarily small, i.e. $\lambda'\lambda'' \leq 10^{-24}$. If one is restricted to the Supersymmetric Standard Model, the above four couplings are independent, and it would be technically possible to assume the existence of some of them while putting to zero others or setting them to very small values. This is something that cannot be done in GUTs, at least in a straightforward fashion [4]. For example, in minimal $SU(5)$ the first three terms in (1) arise from the R-parity violating coupling

$$\lambda_{ijk}\phi_i(\overline{5})\phi_j(\overline{5})\psi_k(10)\,. \tag{2}$$

Thus, the resulting couplings in (1) would be related as $\lambda_{ijk}=\frac{1}{2}\lambda'_{ijk}=\lambda''_{ijk}$. It is possible however that R-parity violation is absent at the renormalizable level, perhaps because of some other symmetry [5] not directly related to it, and shows up in the form of effective non-renormalizable interactions suppressed by the breaking scale of the symmetry over some large mass scale. The required smallness of these couplings, coming mainly from the need to suppress proton decay, can be accounted for by establishing a large hierarchy among the B- and L-violating effective strengths. $SU(5)$ models with the requred $\lambda'' \ll \lambda'$ disparity in the effective R-parity non-conserving strengths have been recently discussed [4],[5]. In contrast to R-parity non-conservation [6] through L-number violation ($\lambda'' \ll \lambda'$), which has received considerable attention, the opposite case of R-non-conservation exclusively through the Baryon Number violating interaction

$$\lambda''_{ijk}d_i^cd_j^cu_k^c \tag{3}$$

has received much less attention and only within the Supersymmetric Standard Model. The phenomenological profile of low-energy Baryon Number violation through (3) includes neutron–antineutron oscillations, double nucleon decay (in nuclei), as well as various exotic non-leptonic heavy meson decays. The presence of (3), while all the other terms in (1) are absent, clearly requires a strong asymmetry between quarks and leptons, which cannot be accounted for in conventional GUTs. Nevertheless, such GUTs can certainly be constructed. In the present short article we construct two such models, an $SU(5)$ model and a flipped $SU(5)\times U(1)_X$ model, in which R-parity is violated exclusively through the operators (3). These models, although entirely realistic, are only technically natural, as all existing GUTs. They demonstrate that gauge coupling unification, an almost "experimental" fact, is certainly compatible with an extreme disparity between quarks and leptons as far as their R-parity violation behaviour is concerned.

2. An SU(5) model. The so-called *missing-doublet $SU(5)$ model* [7] was constructed in order to avoid the fine numerical adjustment in the triplet–doublet mass splitting required in the minimal supersymmetric $SU(5)$ model [8]. The generic missing-doublet $SU(5)$ model has a Higgs superfield Σ in the **75** representation, instead of the usual adjoint and an extra pair of superfields $\Theta, \overline{\Theta}$ in the $\mathbf{50}+\overline{\mathbf{50}}$ representation. The superpotential is

$$W = Y_{ij}^{(u)}\psi_i\psi_j H + Y_{ij}^{(d)}\psi_i\phi_j\overline{H} + \lambda\overline{H}\Sigma\Theta + \overline{\lambda}H\Sigma\overline{\Theta} + \frac{1}{2}\mu_\Sigma Tr(\Sigma^2) + \frac{h}{3}Tr(\Sigma^3) \tag{4}$$

where $\psi_i(10)$, $\phi_i(\overline{5})$ are the standard three families and $H(5) = (H^c, D)$, $\overline{H}(\overline{5}) = (H, D^c)$ the electroweak Higgs pentaplets. Note that the $SU(5)$-breaking v.e.v. $\langle\Sigma\rangle$ pairs the coloured triplets D, D^c to the analogous coloured triplets θ, θ^c in the $\mathbf{50}+\overline{\mathbf{50}}$. The rest of the ingredients of the $\mathbf{50}+\overline{\mathbf{50}}$ can receive a mass either through a direct term $M_\Theta\Theta\overline{\Theta}$ or through a coupling $\Theta\Sigma\overline{\Theta}$. In the latter case, the gauge coupling blows up before we reach the Planck mass M_P and the model ceases to be perturbative. The same happens if M_Θ is of the order of the unification scale. If M_Θ is of the order of M_P, perturbativity is valid. In this case one pair of triplets, via a see-saw type mechanism, receives a mass of order $\langle\Sigma\rangle^2/M_\Theta$, which is two orders of magnitude below the unification scale and, therefore, problematic for proton stability due to the presense of $D = 5$ operators. This problem is avoided in the Peccei–Quinn version of the model[9] which starts with two pairs of pentaplets and two pairs of Planck-mass $\mathbf{50}+\overline{\mathbf{50}}$'s and ultimately ends up with an additional pair of intermediate mass (10^{10}-10^{12} GeV) isodoublets. What we are about to discuss in relation to R-parity applies equally well to either version of the model. Thus, for simplicity , we shall be referring to the generic superpotential (4). Note however that the Peccei–Quinn version is in agreement with low energy data [9].

The superpotential (4) is exactly R-parity conserving. Let us introduce now an extra sector of massive fields $R(50) + \overline{R}(\overline{50}) + \eta(5) + \overline{\eta}(\overline{5})$ in more than one family replicas. All these fields will have $O(M_P)$ masses so that perturbativity and particle content below M_P will be unaffected. The new sector breaks R-parity through the interactions

$$\Delta W_R = \lambda_i\phi_i\Sigma R_i + f_{ijk}\psi_i\overline{\eta}_j\overline{\eta}_k + f_i\eta_i\Sigma\overline{R}_i + M_{Ri}R_i\overline{R}_i + M_{\eta i}\eta_i\overline{\eta}_i\,. \tag{5}$$

It is evident that for a SM-preserving v.e.v. of Σ , the left-handed leptons in ϕ will not communicate with the contents of ψ through the interactions (5), since R contains only coloured components and a charged isosinglet.

Denoting by Δ_{0i}, Δ_{0i}^c the triplets in R_i, $\overline{R}_i$ and by δ_{0i}, δ_{0i}^c the corresponding ones in η_i, $\overline{\eta}_i$ we obtain the triplet mass matrix

$$M^{(3)} = \begin{bmatrix} M_R & fv & 0 \\ 0 & M_\eta & 0 \\ \lambda v & 0 & 0 \end{bmatrix} \tag{6}$$

in a Δ_0^c, δ_0^c, d_0^c/Δ_0, δ_0 basis. The combination

$$d^c = N(d_0^c - (\lambda v/M_R)\Delta_0^c + (\lambda f v^2/M_R M_\eta)\delta_0^c) \tag{7}$$

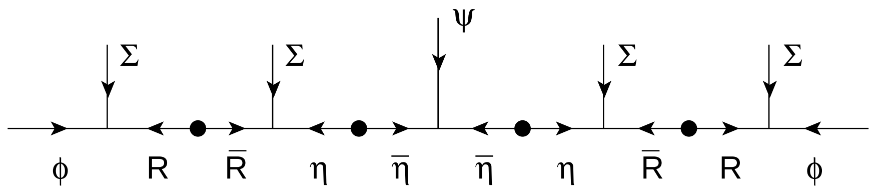

Fig. 1

with $N^{-1/2} = 1+(\lambda v/M_R)^2(1+(fv/M_\eta)^2)$, stays massless. Rewriting (5) in terms of the mass eigenstates and integrating out the massive ones, we obtain an effective non-renormalizable interaction term

$$f_{ijk}^{eff}(v/M)^4(u_i^c d_j^c d_k^c) \tag{8}$$

which violates R-parity exclusively through the quark superfields.

Another way to understand the effective interaction (6) is through the graph of the figure, which generates the effective F-term

$$(\psi_k)_{MN}(\phi_i)^{M'}(\phi_j)^{N'}\omega^{MN}_{M'N'} \tag{9}$$

with $\omega^{MN}_{M'N'} = \omega^M_{M'}\omega^N_{N'}$ and

$$\omega^A_B = \epsilon^{ACDEF}\epsilon_{BGHIJ}\Sigma^{GH}_{LM}\Sigma^{PQ}_{CD}(\delta^L_P\delta^I_E\delta^M_Q\delta^J_F + \cdots)\,. \tag{10}$$

The dots imply symmetrization with respect to L, I and M, J and antisymmetrization with respect to L, M and I, J. Substituting the $SU(3)_C \times SU(2)_L \times U(1)_Y$ invariant v.e.v.

$$\langle\Sigma^{BC}_{DE}\rangle = v((\delta_c)^B_D(\delta_c)^C_E + 2(\delta_w)^B_D(\delta_w)^C_E - \frac{1}{2}\delta^B_D\delta^C_E - (B \leftrightarrow C)) \tag{11}$$

we end up with

$$\omega^A_B \propto v^2(\delta_c)^A_B\,. \tag{12}$$

The subscript c denotes the $SU(3)_C$ direction.

Note that (5) is only technically natural. Even in the Peccei–Quinn version of the model, the symmetries allow R, $\overline{R}$ to be replaced by Θ, $\overline{\Theta}$. This should not be allowed, however, and the R-parity sector should not interact with the rest of the theory apart from the interactions appearing in (5).

3. An $\mathbf{SU(5) \times U(1)_X}$ model. In the previously analysed $SU(5)$ model, the R-parity non-conserving interactions were restricted to quark superfields by virtue of the choice of the Higgs representations employed. Another possibility would be to construct GUTs with a built-in quark–lepton asymmetry by virtue of modifications in the matter representations themselves. Such a *de-unification* is already partially realized in the flipped $SU(5) \times U(1)_X$ model [10], in which the right-handed leptons have been removed from the rest of the quark and lepton representations and are introduced as $SU(5)$ singlets . As a result, no relation between quark and charged lepton masses exists in this model. In what follows we shall

construct an $SU(5)\times U(1)_X$ model with exclusively $\Delta B=1$, $\Delta L=0$ R-parity violating interactions. Our strategy will be to remove the left-handed leptons from the $(\overline{\mathbf{5}},-\mathbf{3})$ representation in which they cohabit with the up antiquarks. Then, R-parity non-conserving interactions of the type $d^cd^cu^c$ will not necessarily coexist with those of the d^cql type.

The standard Higgs fields of the flipped $SU(5)\times U(1)_X$ model are

$$\mathcal{H}(\mathbf{10},\mathbf{1})+\overline{\mathcal{H}}(\overline{\mathbf{10}},-\mathbf{1})+h(\mathbf{5},-\mathbf{2})+\overline{h}(\overline{\mathbf{5}},\mathbf{2})=$$
$$(q_H,d_H^c,\nu_H^c)+(\overline{q}_H,\overline{d}_H^c,\overline{\nu}_H^c)+(H,D)+(H^c,D^c)\,. \tag{13}$$

The breaking $SU(5)\times U(1)_X\rightarrow SU(3)_C\times SU(2)_L\times U(1)_Y$ is achieved with a v.e.v. in the D-flat direction $\langle\nu_H^c\rangle=\langle\overline{\nu_H^c}\rangle=v$. The coloured triplets d_H^c, $\overline{d_H^c}$ that survive the Higgs phenomena combine into massive states with the triplets D, D^c through the couplings

$$W_1=\lambda_1\mathcal{H}\mathcal{H}h+\lambda_2\overline{\mathcal{H}\mathcal{H}h}=(\lambda_1v)d_H^cD+(\lambda_2v)\overline{d}_H^cD^c+\cdots \tag{14}$$

Consider now a complete matter family

$$\mathcal{F}(\mathbf{10},\mathbf{1})+f^{c\prime}(\overline{\mathbf{5}},-\mathbf{3})+e^c(\mathbf{1},\mathbf{5})=(q,d^c,\nu^c)+(l',u^{c\prime})+e^c\,. \tag{15}$$

The prime on $f^{c\prime}(\overline{\mathbf{5}},-\mathbf{3})$ indicates that its contents should not be identified yet with quarks or leptons. Next, we introduce additional "matter" superfields

$$f^{c\prime\prime}(\overline{\mathbf{5}},-\mathbf{3})+f''(\mathbf{5},\mathbf{3})+\phi^c(\overline{\mathbf{5}},\mathbf{2})+\phi(\mathbf{5},-\mathbf{2})=(l'',u^{c\prime\prime})+(l^{c\prime\prime},u'')+(\lambda^c,\delta^c)+(\lambda,\delta)\,. \tag{16}$$

The component fields transform under $SU(3)_C\times SU(2)_L\times U(1)_Y$ as $(\mathbf{1},\mathbf{2},-\frac{\mathbf{1}}{\mathbf{2}})$ and $(\mathbf{1},\mathbf{2},\frac{\mathbf{1}}{\mathbf{2}})$ isodoublets, namely (l'',λ) and $(l^{c\prime\prime},\lambda^c)$ correspondingly, and as coloured triplets

$$u^{c\prime\prime}(\overline{\mathbf{3}},\mathbf{1},-\frac{\mathbf{2}}{\mathbf{3}}),\ u''(\mathbf{3},\mathbf{1},\frac{\mathbf{2}}{\mathbf{3}}),\ \delta^c(\overline{\mathbf{3}},\mathbf{1},\frac{\mathbf{1}}{\mathbf{3}}),\ \delta(\mathbf{3},\mathbf{1},-\frac{\mathbf{1}}{\mathbf{3}})\,. \tag{17}$$

Out of all the fields $f^{c\prime},f^{c\prime\prime},f'',\phi^c,\phi$, only one isodoublet and only one colour triplet of charge $-2/3$ will survive massless. In order to achieve this, an extra massive pair of decaplets $\mathcal{H}'(\mathbf{10},\mathbf{1})+\overline{\mathcal{H}}'(\overline{\mathbf{10}},-\mathbf{1})$ has to be introduced. Note that all introduced extra fields belong to representations that arise in the superstring version of the model [11]. A four-dimensional superstring model having the above field content, as well as the interactions of the GUT at hand, could in principle be constructed.

These fields interact through the superpotential interactions

$$W_2=M_1\overline{\mathcal{H}}'\mathcal{H}'+M_2f''f^{c\prime\prime}+\lambda_3\mathcal{H}'\mathcal{H}\phi+\lambda_4\overline{\mathcal{H}}'\overline{\mathcal{H}}'\phi^c+\lambda_5f^{c\prime}\phi^c\mathcal{H}+\lambda_6f''\phi\overline{\mathcal{H}}=$$
$$M_1(\overline{q}_H'q_H'+\overline{\nu}_H^{c\prime}\nu_H^{c\prime}+\overline{d}_H^{c\prime}d_H^{c\prime})+M_2(u^{c\prime\prime}u''+l^{c\prime\prime}l'')$$
$$+(\lambda_3v)d_H^{c\prime}\delta+(\lambda_4v)\overline{d}_H^{c\prime}\delta^c+(\lambda_5v)l'\lambda^c+(\lambda_6v)l^{c\prime\prime}\lambda\,. \tag{18}$$

According to (18) the pairs $(q_H',\overline{q}_H')$ and $(\nu_H^{c\prime},\overline{\nu}_H^{c\prime})$ get a mass M_1 and the pair $(u'',u^{c\prime\prime})$ gets a mass M_2. The combinations

$$(d_H^c)_\pm=[(\lambda_4v)d_H^{c\prime}-M_\pm\delta^c]/\sqrt{M_\pm^2+(\lambda_4v)^2} \tag{19}$$

$$(\overline{d}^c_H)_\pm = [(\lambda_3 v)\overline{d}^{c\prime}_H - M_\pm \delta]/\sqrt{M_\pm^2 + (\lambda_3 v)^2} \tag{20}$$

get a mass $M_\pm = \frac{1}{2}(M_1 \pm \sqrt{M_1^2 + 4\lambda_3\lambda_4 v^2})$. The pair l', λ^c gets a mass $\lambda_5 v$, so that $f^{c\prime}$ does not contain any leptons. The combination

$$[M_2 l'' + (\lambda_6 v)\lambda]/\sqrt{M_2^2 + (\lambda_6 v)^2} \tag{21}$$

forms a massive state of mass $[M_2^2 + (\lambda_6 v)^2]^{\frac{1}{2}}$ with $l^{c\prime\prime}$. The surviving massless left-handed lepton is the combination

$$l = [(\lambda_6 v) l'' - M_2 \lambda]/\sqrt{M_2^2 + (\lambda_6 v)^2}\,. \tag{22}$$

Finally, the field $u^{c\prime}$ stays massless. Thus, it can be identified with an up antiquark and we can drop the prime when referring to it. It should be admitted that the choice of W_2 is only technically natural and interaction terms that would drastically change the obtained mass pattern are possible. But naturalness is a general problem of GUTs.

It should be pointed out that the key ingredient of the present model is that "matter-like" isodoublets and "Higgs-like" ones can obtain superheavy masses through the couplings $f^c \phi^c \mathcal{H}$. Note that the coloured triplets contained in the pentaplets are of different charge and stay massless. This is in a way the opposite of what happens through the couplings $\mathcal{H}\mathcal{H}h$. There, when the decaplet gets a v.e.v., the coloured triplets in $\mathcal{H}$ and h pair to obtain a mass while the isodoublet in h is left massless.

Below the $SU(5) \times U(1)_X$ breaking scale the model has the MSSM particle content. Quark and lepton masses arise through the standard Yukawa couplings

$$W_3 = Y^{(d)}\mathcal{F}\mathcal{F}h + Y^{(u)}\mathcal{F}f^{c\prime}\overline{h} + Y^{(u)\prime}\mathcal{F}f^{c\prime\prime}\overline{h} + Y^{(e)\prime}f^{c\prime}e^c h + Y^{(e)}f^{c\prime\prime}e^c h \tag{23}$$

$$= Y^{(d)}qHd^c + Y^{(u)}qu^cH^c + \frac{(\lambda_6 v)}{\sqrt{M_2^2 + (\lambda_6 v)^2}}(Y^{(u)\prime}l\nu^cH^c + Y^{(e)}lHe^c) + \cdots \tag{24}$$

The dots signify terms that involve superheavy fields. The coupling $Y^{(e)\prime}$ does not contribute to quark–lepton masses while $Y^{(u)\prime}$ contributes only to a Dirac neutrino mass. Note that right-handed neutrinos can obtain a large Majorana mass through the non-renormalizable interactions $\mathcal{F}\mathcal{F}\overline{\mathcal{H}\mathcal{H}}/M = (v^2/M)\nu^c\nu^c + \cdots$. The mass scales M_1 and M_2, since they are not related to the $SU(5)\times U(1)_X$ breakdown scale, are not necessarily of that order. In fact, their natural values are of the order of the Planck scale or the string scale. In that case, lepton masses carry a suppression factor $\lambda_6 v/M_2$. Note that in this case the triplets $(d^c_H)_-, (\overline{d}^c_H)_-$ have a mass $(\lambda_3 v)^2/M_1$, somewhat lower than the $SU(5)\times U(1)_X$ breaking scale. This would only have a very minor consequence on the Renormalization Group analysis and no other effect since these coloured triplets do not appear in the Yukawa couplings of quark–lepton bilinears. Of course, alternatively it is technically natural to take the scale M_2 to be of the same order as λv.

Up to now we have considered only one family. A three-generation model with all three left-handed leptons removed from the $(\overline{\mathbf{5}}, -\mathbf{3})$ representations that contain the up antiquarks

would require a triplication of the additional sector that has been introduced. In the case when the scales M_1 and M_2 are of order M_P, the one-family model aquires just one extra pair of pentaplets, massless above the $SU(5) \times U(1)$ breaking scale. This does not have any drastic influence on a possibly anticipated unification of the $SU(5)$ and $U(1)_X$ couplings. In the extreme case of three extra pairs of pentaplets above the GUT scale, the $SU(5)$ beta function at one loop vanishes. Of course, it is possible that the left-handed lepton "misplacement" occurs only for one generation, possibly the third, and that the previously described sector of massive fields is sufficient.

R-parity is still a symmetry of the effective theory below the GUT scale. Effective operators that could break R-parity are

$$\mathcal{F}\mathcal{F}\phi,\ \mathcal{F}\mathcal{F}\mathcal{H}f^c,\ \mathcal{H}f^c f^c e^c\,. \tag{25}$$

These operators cannot be generated as effective F-terms by the interactions appearing in W_1, W_2 and W_3. Nevertheless, it is straightforward now to introduce R-parity violation in the desired baryonic direction by modifying the model so that it contains an extra supermassive pair of pentaplets

$$\chi(\mathbf{5},\mathbf{-2}) + \chi^{\mathbf{c}}(\overline{\mathbf{5}},\mathbf{2}) \tag{26}$$

interacting with the rest of the theory exclusively through the interactions

$$W_4 = M_3\chi\chi^c + \lambda_{ij}\mathcal{F}_i\mathcal{F}_j\chi + \lambda\mathcal{H}f_k^{c\prime}\chi^c\,. \tag{27}$$

An effective F-term that involves only quark superfields and violates R-parity can now be generated. It is

$$\frac{\lambda\lambda_{ij}}{M_3}\mathcal{F}_i\mathcal{F}_j f_k^{c\prime}\mathcal{H}\,. \tag{28}$$

The index k refers to the generation with the misplaced lepton. For example, in the case that k corresponds to the third generation, the generated effective operator will be $d_i^c d_j^c t^c$. If we assume that no other R-parity non-conserving interactions are present apart from those appearing in W_4, no other effective F-terms, such as $\mathcal{F}\mathcal{F}f^{c\prime\prime}\mathcal{H}$ or $\mathcal{H}f^{c\prime}f^{c\prime\prime}e^c$, will appear.

4. Discussion. The Baryon Number violating operators under discussion have various, in principle testable, phenomenological implications, and each of them can provide us with information on the effective coupling constants involved. The effect of these interactions in hadron collider experiments is expected to be difficult to test since these interactions lead to multijet production which suffers from a tremendous QCD background. Cascade decays however, could lead to more easily identifiable signals [6]. Nevertheless, collider processes can be used in order to derive bounds on these couplings. Considering the contribution of these couplings to the Z decay into $b, \overline{b}$ or leptons, with the present state of the data, does not lead to any interesting bound [12]. Both models presented here satisfy trivially these bounds. There is virtually no cosmological bound on these couplings either. Such bounds are in general derived by requiring the survival of early baryogenesis until the present epoch. It has been shown that for the exclusively Baryon Number violating operators $d^c d^c u^c$ no bound is derived and all that is required is an initial flavour asymmetric Lepton Number asymmetry [13]. The strongest constraints on these couplings come from neutron–antineutron

oscillations and heavy nuclei decays [14],[15]. Neutron–antineutron oscillations constrain the $d^c b^c u^c$ coupling while the $d^c s^c u^c$ coupling is strongly bounded by the non-observation of double-nucleon decay into kaons. For squark masses of the order of 300 GeV , these bounds are $\lambda''_{udb} \leq 5 \times 10^{-3}$, $\lambda''_{uds} \leq 10^{-6}$. Additional bounds on products of these couplings have been recently [16] obtained from the consideration of rare two-body non-leptonic decays of heavy quark mesons (mostly B).

The approximate R-parity conservation required by any phenomenologically viable version of the Supersymmetric Standard Model is one of the intriguing questions of supersymmetric model building. This is dramatically encountered in Superstring derived models where in general R-parity is not a symmetry and special care has to be taken so that it is not badly broken. Assuming of course that low-energy supersymmetry is realized in nature, it might very well be that R-parity is an exact symmetry. Neither Superstrings nor GUTs have yet provided any convincing argument why it should be so. Thus the possibility of R-parity non-conservation remains open. The models discussed in the present article are realistic examples of GUTs, i.e.theories realizing the gauge coupling unification suggested by low-energy electroweak data, which at the same time exhibit R-parity non-conservation. These models demonstrate the compatibility of unification and R-parity breaking exclusively through Baryon Number violation. Although this type of R-parity breaking would not necessarily be the easiest to observe, its rare phenomenological profile would certainly provide evidence for supersymmetry.

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